Attachment A:

Calculation of constituent emission rates at the MACT emission limit for the Veolia Incineration Facility; Sauget, Illinois

Converting MACT Standards to Mass Emission Rates for Risk Assessment of Incinerator Stack Emissions at Veolia ES Technical Solutions, L.L.C (formerly Onyx Environmental Services, Inc., formerly Trade Waste Incineration)

Sauget, Illinois

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I. Background

The United States Environmental Protection Agency (U.S. EPA) and Veolia ES Technical Solutions, L.L.C., Sauget (Veolia-Sauget) have each independently modeled theoretical emissions from Veolia-Sauget's three stacks in Sauget, Illinois and conducted risk assessments of those emissions based on the surrounding community's attributes. One objective for U.S. EPA was to check the allowable emissions under the [illegible] to see if these limits were associated with unacceptable risk in the community. The MACT standards are expressed as a concentration referenced to certain standard stack conditions. However, these conditions vary from stack to stack such that the mass emission rate (of a specific pollutant like mercury) in compliance with the MACT may be different at each stack. U.S. EPA requires actual mass flow rates in order to estimate risks. Therefore, U.S. EPA examined a selection of emission test observations for each stack and, coupled with the stack characteristics used in the dispersion modeling, converted the MACT standards into mass emission rates as described herein. The calculations described below are shown in full for all parameters in the attached spreadsheet.

II. Modeled Stack Parameters

The following table lists stack parameters used in the dispersion modeling. The stack diameter and modeled flow velocity were identified as source characteristics in Veolia-Sauget's October 27, 2005 *Onyx Environmental Services, Rotary Kiln and Fixed Hearth Incinerators, Screening Level Human Health Risk Assessment Report-Revised.*

Stack	Stack 2	Stack 3	Stack 4
diameter (meters)	[illegible]	[illegible]	[illegible]
modeled emission flow velocity (m/s)	20.2	20.2	20.4
actual measured flow velocity (m/s) as reported in selected emission tests	16.5-18.3*	19.6-20.6*	19.1-23.7

Note: Actual flow velocities reported in emission testing for stacks 2 and 3 corresponded to the stack diameter at the sampling port which was wider than that of top of the stack. The measured flow velocities were adjusted for the stack exit constriction (from a diameter of 0.9906 meters to 0.6858 meters) assuming no appreciable change in gas density.

The source characteristics reported by Veolia-Sauget were also used in U.S. EPA dispersion modeling efforts. Since the Agency dispersion modeling effort was carried out at these conditions, we preferred to match the emission rates at the MACT standards to these modeled conditions rather than to those of a specific emission test. It is worth noting that the flow velocity observations for the selected Stack 2 emission tests were somewhat lower than the source characteristic provided by Veolia-Sauget. The flow velocities for Stacks 3 and 4 provided by Veolia-Sauget as source characteristics were consistent with the emission test observations.

III. Conversion from MACT rates

The MACT standards for mercury, dioxin, and various metals are given as a dry gas concentration at standard temperature, pressure, and a referenced stack gas oxygen content. However, the observed stack conditions vary from these standard reference points and appropriate conversions are made.

A. Emission Test Observations

At the time the calculation was prepared, the observations from the following emission tests were on-hand:

Stack 2	Two tests from September 2003 and one test from May 2004
Stack 3	One test from June 2002 and one from August 2002
Stack 4	One test each from June 2002, August 2002, and May 2004

B. Converting from wet actual stack flow to dry standard stack flow.

In order to convert to dry standard conditions, the actual stack pressure, stack temperature, and moisture content are used as follows:

$$dscms = velocity_{stack,actual} \times Area_{stack} \times \frac{temp_{std}}{temp_{stack}} \times \frac{pressure_{stack}}{pressure_{std}} \times (1 - volumetric\ moisture\ content)$$

Ultimately, we will need to relate the MACT standards to the wet flow rates used in the dispersion modeling. Therefore we examined the conversion of actual conditions to dry standard flow as expressed in a single conversion factor for each unique emission test run. The factor is simply a ratio of the dry standard flow rate to that of the actual flow rate. These conversion factors were consistent from run to run for each stack. Minimum, maximums, and average conversion factors where applied to the modeled stack conditions, however, the values did not vary greatly and the average conversion factors were used for subsequent calculations.

C. Oxygen Content

The measured oxygen content from the emission test observations was consistent for each stack. Therefore, an average stack oxygen content was used to convert the MACT limits to stack oxygen conditions. The stack specific MACT standard is calculated as follows:

$$MACT_{stack specific} = (MACT) \times \left(\frac{21 - O_2\ content_{stack specific}}{14} \right)$$

D. Example Calculation

As an example, here is how we calculated the emission rate of mercury at the MACT standard for stack 4. The mercury MACT standard is 130 micrograms per dry standard cubic meter (μg/dscm) referenced to 7% oxygen content.

For stack 4:

stack diameter	=	1.2192 meters
stack exit flow velocity	=	20.4 meters/second (from Veolia-Sauget)
stack exit cross sectional area	=	1.167 square meters
[illegible]		23.82 cubic meters per second (calculated)

The stack exit volumetric flow rate can be converted to dry standard cubic meters per second by multiplying by the ratio of calculated dry standard flow rates to wet actual flow rates from emission tests. An example calculation from the June 2002 stack 4 emission test follows:

stack temperature	=	376.4°F	=	836.07°R
stack pressure	=	29.52 inches of mercury		
stack volumetric moisture content	=	37.869 %		
stack oxygen content	=	13.6 %		

$$Conversion\ Factor = \frac{dry\ std.\ flowrate}{wet\ actual\ flowrate} = \frac{temperature_{std}}{temperature_{stack}} \times \frac{pressure_{stack}}{pressure_{std}} \times (1 - volumetric\ moisture\ content)$$

$$\frac{528°R}{836.07°R} \times \frac{29.52\ in.Hg}{29.92\ in.Hg} \times (1 - 0.37869) = 0.387$$

The average conversion factor for stack 4 over the three emission tests was 0.379. Thus, the dry standard flow rate for stack 4 as modeled for the risk assessment is 23.82 x 0.379, or 9.03 dry standard cubic meters per second.

The oxygen adjusted Hg MACT limit for stack 4, based on an average oxygen content observed during the emission tests of 13.38% is calculated as follows:

$$MACT_{stack\ specific} = \left(\frac{130\ \mu g}{dry\ std.\ m^3}\right) \times \left(\frac{21 - 13.38}{14}\right) = \frac{70.76\ \mu g}{dry\ std.\ m^3}$$

All that remains is to multiply our stack specific MACT concentration by the dry standard flow rate to get the mass emission rate at the MACT standard.

$$stack\ 4\ Hg\ emission\ rate = \frac{70.76\ \mu g}{dry\ std.m^3} \times \frac{9.03\ dry\ std.m^3}{second} = \frac{638.96\ \mu g}{second} = \frac{0.000639\ g}{second}$$

IV. Conversion Summary

The conversion of MACT limits to mass emission rates was completed for all three incinerators at Veolia-Sauget. The results are summarized in the following table:

Parameter	Stack 2 fixed-hearth dual-chamber	Stack 3 fixed-hearth dual-chamber	Stack 4 rotary kiln incinerator
stack diameter (meters)	0.6858	0.6858	1.2192
modeled stack gas exit velocity (m/s)	20.2	20.2	20.4
modeled stack gas exit flow rate (m^3/s)	7.46	7.46	23.82
average conversion factor from actual flow to dry standard flow	0.353	0.408	0.379
average dry standard flow rate (dscm/s)	2.63	3.05	9.03
average stack oxygen content	11.4%	12.9%	13.38%
dioxin/furan emission rate, g/s (MACT limit of 0.2 ng/dcsm @ 7% O_2)	3.60×10^{-10} g/s	3.52×10^{-10} g/s	9.84×10^{-10} g/s
semivolatile metals (Pb & Cd) emission rate, g/s (MACT limit of 230 µg/dscm @ 7% O_2)	0.000414 g/s	0.000405 g/s	0.00113 g/s
low volatile metals (As, Be, Cr) emission rate, g/s (MACT limit of 92 µg/dscm @ 7% O_2)	0.000166 g/s	0.000162 g/s	0.000453 g/s
mercury emission rate, g/s (MACT limit of 130 µg/dscm @ 7% O_2)	0.000234 g/s	0.000229 g/s	0.000639 g/s

dioxin/furan (ng TEQ/dscm)	0.2
particulate matter (gr/dscm)	0.013
semivolatile metals (ug/dscm) (Pb & Cd))	230
low volatile metals (ug/dscm) (As, Be, Cr)	92
total chlorine (ppmv)	32
mercury (ug/dscm)	130

	Stacks 2	Stack 4	Stack 3	ɔdated Stack 3	
velocity (m/s)	20.2	20.4	20.2	20.2	
stack diameter (m)	0.6858	1.2192	0.6858	0.6858	
stack area (m2) [PI(stack diameter/2)^2]	0.3693897522621	1.167454032	0.3693898	0.3693898	
volumetric flowrate (m3/s) [(stack area)(velocity)]	7.4616729956939	23.81606225	7.461673	7.461673	
minimum conversion factor from wet actual to dry standard flow	0.350378936268	0.355746855	0.4049441	0.3281005	
average conversion factor from wet actual to dry standard flow	[illegible]	[illegible]	[illegible]	[illegible]	
maximum conversion factor from wet actual to dry standard flow	0.3546813881328	0.394960562	0.411562	0.3441997	
minimum flow in dry standard cubic meters per second (dscm/s)	2.6144130470108	8.472489234	3.0215601	2.448179	
average flow in dry standard cubic meters per second (dscm/s)	2.6335272984892	9.032918334	3.0462505	2.4973614	
maximum flow in dry standard cubic meters per second (dscm/s)	2.646516535906	9.406405342	3.0709409	2.5683059	
average stack O2 content (dry)	11.423333333333	13.37666667	12.9	10	

emission rate at the MACT

to convert the MACT limit to stack oxygen conditions:

stack MACT = (MACT limit)(21-stack O2 content)/14

emission rate at the MACT = (stack MACT) (flow in dry standard cubic meters per second)

dioxin/furan (ng TEQ/s) minimum	0.3576766040029	0.922694423	0.3496377	0.39439	
dioxin/furan (ng TEQ/s) average	0.3602916156457	0.983727821	0.3524947	0.402313	
dioxin/furan (ng TEQ/s) maximum	0.3620686670313	1.024402334	0.3553517	0.4137419	
dioxin/furan (g TEQ/s) min	0.0000000003577	9.2269E-010	3.5E-010	3.94E-010	12.80%
dioxin/furan (g TEQ/s) average	0.0000000003603	9.8373E-010	3.52E-010	4.02E-010	14.13%
dioxin/furan (g TEQ/s) maximum	0.0000000003621	0.000000001	3.55E-010	4.14E-010	16.43%
semivolatile metals (ug/s) (Pb & Cd) min	411.32809460339	1061.098586	402.08333	453.54847	
semivolatile metals (ug/s) (Pb & Cd) average	414.33535799255	1131.286994	405.36891	462.65999	
semivolatile metals (ug/s) (Pb & Cd) max	416.37896708603	1178.062684	408.6545	475.80313	
semivolatile metals (g/s) (Pb & Cd) min	0.0004113280946	0.001061099	0.0004021	0.0004535	12.80%
semivolatile metals (g/s) (Pb & Cd) average	0.000414335358	0.001131287	0.0004054	0.0004627	14.13%
semivolatile metals (g/s) (Pb & Cd) max	0.0004163789671	0.001178063	0.0004087	0.0004758	16.43%
previous calculation	0.000426	0.00114	0.000358	0.000358	
	-2.74%	-0.76%	13.23%	29.23%	

low volatile mteals (ug/s) (As, Be, Cr) min	164.53123784136	424.4394345	160.83333	181.41939	
low volatile mteals (ug/s) (As, Be, Cr) average	165.73414319702	452.5147974	162.14756	185.064	
low volatile mteals (ug/s) (As, Be, Cr) max	166.55158683441	471.2250737	163.4618	190.32125	
low volatile mteals (g/s) (As, Be, Cr) min	0.0001645312378	0.000424439	0.0001608	0.0001814	12.80%
low volatile mteals (g/s) (As, Be, Cr) average	0.0001657341432	0.000452515	0.0001621	0.0001851	14.13%
low volatile mteals (g/s) (As, Be, Cr) max	0.0001665515868	0.000471225	0.0001635	0.0001903	16.43%
previous calculation	0.0001722222222	0.000461111	0.0001444	0.0001444	
	-3.77%	-1.86%	12.26%	28.12%	
mercury (ug/s) min	232.48979260192	599.7513748	227.26449	256.35348	
mercury (ug/s) average	234.1895501697	639.4230833	229.12156	261.50347	
mercury (ug/s) max	235.34463357036	665.8615172	230.97863	268.9322	
mercury (g/s) min	0.0002324897926	0.000599751	0.0002273	0.0002564	12.80%
mercury (g/s) average	0.0002341895502	0.000639423	0.0002291	0.0002615	14.13%
mercury (g/s) max	0.0002353446336	0.000665862	0.000231	0.0002689	16.43%
previous calculation	0.000236	0.000625	0.000194	0.000194	
	-0.77%	2.31%	18.10%	34.80%	

my estimated total mercury at MACT	7385.4016541517	20164.84636	7225.5775	34775.825	grams/year
	grams/year	grams/year	grams/year	76.506816	lbs per year

calculated stack MACT emission rates specific to each burn	0.0002638113047	0.000528348	0.0001907	0.0002462	
to compare to the "average" values at dispersion model conditions	0.0002138657881	0.000511747	0.0002043	0.000253	
above	0.000223062966	0.000640399		0.0002732	
average	0.0002335800196	0.000560165	0.0001975	0.0002574	30.35%
	-0.26%	-12.40%	-13.80%		12.36%

Result: Average stack MACT emission rates are conservative and will be used for the risk assessment

Risk Emission Limits at the MACT which
correspond to the conditions used in the dispersion model

	Stack 2	Stack 4	Stack 3
dioxin/furan TEQ g/s	3.60E-010	9.84E-010	3.52E-010
semivolatile metals (g/s) (Pb & Cd))	4.14E-004	1.13E-003	4.05E-004
low volatile metals (g/s) (As, Be, Cr)	1.66E-004	4.53E-004	1.62E-004
mercury (g/s)	2.34E-004	6.39E-004	2.29E-004